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FOREST SERVICE, U. S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA.

NOISE ABATEMENT IN A PINE PLANTATION

Abstract. — Observations on sound propagation were made in two red pine plantations. Measurements were taken of attenuation of prerecorded frequencies at various distances from the sound source. Sound absorption was strongly dependent on frequencies. Peak absorption was at 500 Hz.

Forest vegetation has been shown to be effective in deadening unwanted sounds. However, people often attribute such vegetation with almost mystical qualities in filtering out unwanted noise. To help clarify the complex effect of forest vegetation on sound, we studied the attenuating effect of two red pine plantations on selected frequencies of sound.

When considering a medium for sound propagation, such as a stand of trees, it is important to have some feeling for what the sound field looks like. An environment in which there are no reflecting or absorbing objects is known as a free field. In such a field, attenuation of sound is predictable. Attenuation in non-free fields is more than that in free fields and is much more difficult to predict. In nature, there are few free fields; reflecting and absorbing objects may range from a few sunflower plants to a dense thicket of vegetation.

Referring to sound abatement by trees is not definite enough to be of use. It is necessary to specify the physical aspects of the vegetation by species composition, plant density, average height, and so on. Of course, these aspects are only indirect indicators of the absorptive, refractive, and reflective properties of the vegetation.

For the relatively simple case of a planted group of trees, the evaluation must include tree heights, diameters, height of clear boles, number of trees per unit area, and other descriptive information. Along with a description of the physical aspects of the vegetation, the orientation of the vegetation arrangement in respect to the source of sound (highway, factory, etc.) must be included.

Stand Descriptions

The two red pine plantations used in this investigation were 37 years old, located on a level glacial outwash plain. Trees were spaced 2 by 2m. in both plantations. Mensurational information for both plantations, henceforth designated as "good" and "poor", is presented in table 1. A more detailed stand description has been published *(Leaf and Leonard 1967)*.

Table 1.—Mensurational data for "Good" and "Poor" pine stands.

Stand	Stem d.b.h. Max.	Stem d.b.h. Min.	Height Max.	Height Min.	Height to live crown	Basal area
	Cm.	*Cm.*	*M.*	*M.*	*M.*	*M.²/ha.*
Good	12.7	10.9	16.2	13.4	8.4	35.0
Poor	11.2	7.4	12.6	7.9	4.9	16.6

These stands constitute two layers: the lower layer of bole space and the fairly dense upper layer of twigs, branches, and needles.

Method

The effect of the forest on the attenuation of sound was determined by measuring the sound pressure level (SPL) at a given audio frequency at several distances from a point source. The resulting SPL's were then plotted as a function of distance from the source of sound. From this plot, the attenuating effect of the forest can be calculated.

This procedure was carried out for frequencies of 125, 250, 500, 1,000, and 2,000 Hz. at 2.6, 16.5, 33, 66, and 82 m. from the source. The human ear can perceive a frequency range from about 20 to 10,000 Hz. (1 Hz. = 1 cycle per sec.).

The sound source was a V. M. Model 27 high fidelity loud speaker

driven by an EICO HF-20 amplifier.[1] In order to insure that identical frequencies were used in all experiments, a set of pure tones of the various frequencies were recorded on a tape loop played into the amplifier from a Wolensack tape recorder. An oscilloscope was used during playback to insure that the signal was not distorted. During field trials, the speaker was placed about 1 m. from the ground and was aimed visually along the selected radii. The speaker had no measureable directivity within 20° of a line parallel to the speaker axis.

A General Radio 1551-C sound level meter was used to measure the SPL at the selected distances. The 1551-C was operated in the "flat" mode with the response in the "slow" position. The microphone was mounted on a tripod about 1.5 m. from the operator. This arrangement placed the microphone about 1 m. from the ground. The 1551-C was calibrated for the extra microphone cable required by this arrangement.

Markers were placed at the required distances along a line of sight determined by a staff compass. If the mark fell too close to a tree or behind a tree, it was moved in an arc until it was midway between stems. During the trials, the microphone was placed directly over the mark. A measurement of the background level was made. If the background was normal—about 40 db. (decibels) SPL—the source operator was signaled to play the first tone. The SPL meter operator watched the meter for the 30-second duration of the tone signal and recorded the "average" SPL. Observation of the same trial by two different operators indicated that this method of estimation yielded results that differed by only 1 or 2 db.

Results and Discussion

The data, consisting of SPL measurements at a given distance, were corrected for background levels when the signal was 10 db. above the background. Plots of SPL over log distance were then prepared. The general equation for the reduction in SPL with distance is:

$$SPL_{r_2} - SPL_{r_1} = 20 \log_{10} (r_1/r_2) + A_e$$

where: r_2, r_1 = distances from source, $r_2 < r_1$, feet and A_e = excess attentuation, db. SPL. The first term on the right accounts for the reduction of SPL in a free field (a field in a homogeneous, isotropic medium free from boundaries). The second term (A_e) includes the attenuating effects of: (1) atmospheric absorption; (2) wind, turbulence,

[1] Mention of a particular product should not be taken as endorsement by the Forest Service or the U. S. Department of Agriculture.

temperature, gradients, ground effects; (3) trees. The term A_e can be evaluated by noting the differences between the measured SPL and that given by the term for the free field losses. The free field loss is a straight line on semilog paper showing a loss of 6 db. SPL for each doubling of distance (fig. 1).

The excess attenuation is the distance between the line for free field loss and measured points.

These experiments were carried out in nearly calm wind and under an overcast sky. Thus the losses due to wind, turbulence, and temperature gradient are small. We assume that the forest floor is a good absorber of acoustic energy. A_e then consists almost entirely of atmospheric absorption and losses attributable to the forest.

The data for frequencies 125 and 2,000 Hz. were scattered about the theoretical loss line, indicating that the forest has little effect at these frequencies (fig. 1). However the excess attenuation for 500 Hz. is quite large. The line for 250 Hz. shows a negative loss, while that for 1,000 Hz. shows a fairly strong loss at distances over 50 feet. These results are confirmed by the data taken in the poor pine stand.

Again, when excess attenuation is plotted over frequency (transfer function), the strong attenuation as 500 Hz. is evident (fig. 2). The clear-cut visual and mensurational differences between the good and poor stands are not reflected in the transfer functions for the two stands.

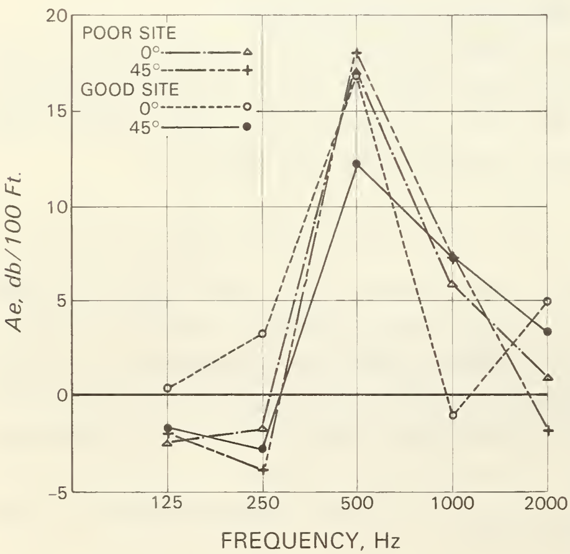
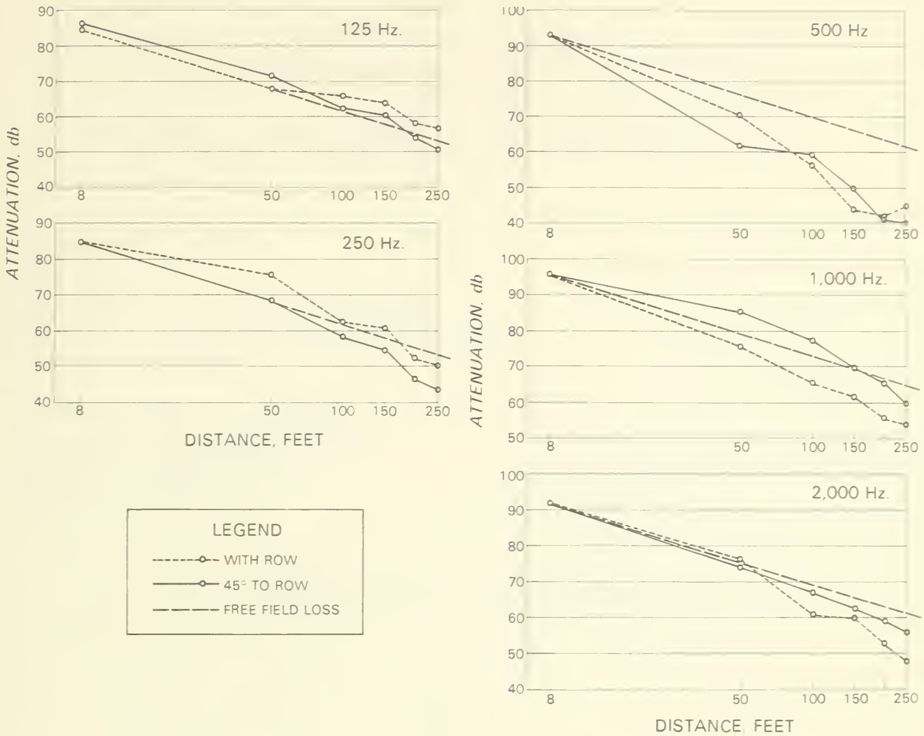


Figure 1. — Sound pressure levels at various distance for the given frequency. Theoretical lines show attenuation due to the inverse square law (free field loss).

Figure 2. — Average excess attenuation at given frequencies.



The presence of strong absorption of sound by a pine forest at 500 Hz. was also shown by Embleton *(1963)*. Embleton attributed the loss to the resonate action of tree branches. Accelerometers attached to selected branches indicated that they did indeed resonate. However, the theory for this action did not predict losses of the order measured.

Our results could be due, at least in part, to reflections from the forest floor. Measurements of the absorptivity of the forest floor are needed. A better practice would be to place the source directly on the ground.

Conclusions

Our results tend to confirm Embleton's work and indicate that the effect of the forest on sound propagation may be quite complex. Studies of physics of sound propagation in the forest are indicated and will promote a better understanding of the effects involved. We feel such studies are preferable to the play-some-sound-and-see-what-happens approach.

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—R. E. LEONARD
Meteorologist
Northeastern Forest Experiment Station
Forest Service, U. S. Department of Agriculture
Syracuse, New York

and L. P. HERRINGTON
Associate Professor of Meteorology
SUNY College of Forestry
Syracuse, New York

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